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FEATURES OF FILM BOILING IN SURFACE WATER COOLING

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FEATURES OF FILM BOILING IN SURFACE WATER COOLING */32

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The results of investigating the heat transfer during the cooling of heated surfaces by water jets or with the aid of injectors are discussed. A study is also made as to the dependence of the second critical load during film boiling on the specific water discharge and a number of other factors.

During forced cooling, the surface of a specimen preheated to 1050°C was cooled by swirl injectors at specific water discharge per unit of cooling surface from 6 to 40 $m^3/m^2 \cdot hr$. In case of the jet method, cooling was accomplished with water jets at discharge rates of up to 30 m/sec.

The preheated steel or copper specimen was cooled in a test stand by one of the enumerated methods. With the aid of a chromel-aluminum thermocouple mounted to the center of the sample and an EPP-09 potentiometer, a temperature curve of the cooling was plotted.

The actual values (α_{act}) of the heat transfer coefficient were determined by the method of regular regime.

For control purposes, we computed the values of the mean heat transfer coefficients for the given temperature range with the aid of approximate integration methods and compared these values with the α_m-values obtained with the Budrin diagrams. In this respect, we usually obtained a satisfactory coincidence.

As is apparent from Fig.1, the forced cooling process is divided into the

* Numbers in the margin indicate pagination in the original foreign text.

following stages: a) establishment of the process; b) stage of a stable film envelope, characterized by the presence of film boiling and considerable reduction in the heat transfer coefficient; c) rupture of the film; d) stage of convective heat transfer without boiling.

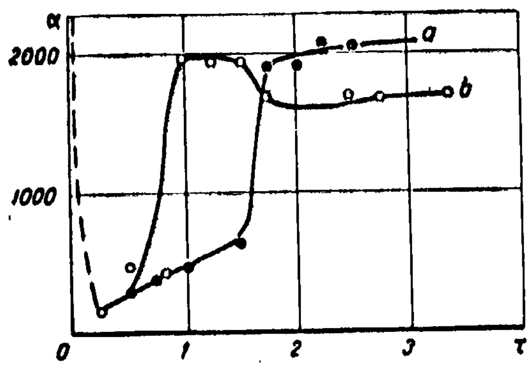

Fig.1 Example of the Variation in α ($w/m^2 \cdot deg$) during Forced Cooling of a Specimen and at Differing Specific Coolant Discharge per Unit Surface
a - 8 $m^3/m^2 \cdot hr$; b - 46 $m^3/m^2 \cdot hr$

In the investigation of heat transfer in a large volume in presence of a fluid freely flowing about a heated surface, Borishanskiy observed a considerable increase in the heat transfer coefficient, associated with initiation of nucleate boiling after rupture of the film. Under our experimental conditions, we noted no appreciable increase in heat transfer following film rupture; evidently this can be explained by the mechanical effect of the water jet. /33

A typical feature of injection cooling is a variation, within wide limits, of the second critical point q_{2cr}. Under the conditions of the Kutateladze and Borishanskiy tests, at $P = 9.8 \times 10^4$ N/m^2, a value of q_{2cr} = (197 - 255) 10^3 w/m^2, is obtained, while under our conditions q_{2cr} fluctuates from 139 to 557×10^3 w/m^2.

Petukhov and Kovalev (Bibl.3) showed during subsequent investigations that the absolute value of the second critical point is much less than that obtained

in the tests conducted by the TsKTI (Central Boiler and Turbine Institute).

The authors of this report consider that the Borishanskiy experiments correspond to a transitional or equilibrium thermal load, at which both film and nucleate boiling are able to exist. Since the order of magnitude of values obtained in our tests is close to the values given above, evidently an equilibrium thermal load occurs under these conditions.

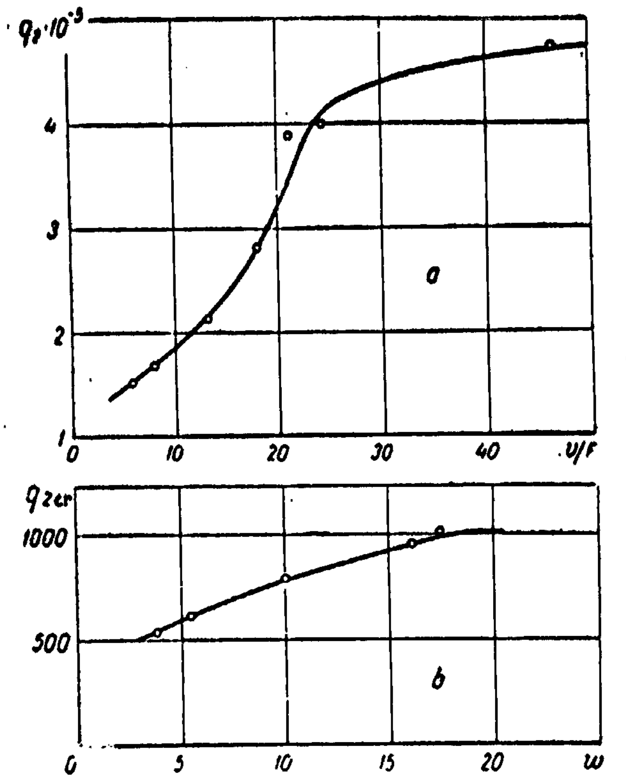

Fig.2 Second Critical Load q_{2cr} as a Function of Specific Water Discharge per Unit Surface during Injection Cooling of the Heated Surface (a) and of the Discharge Rate during Jet Cooling of the Surface (b)
$t_{init} = 1050^{\circ}C$; $\ell = 150$ mm; and $t_{wa} = 20^{\circ}C$

As is apparent in Fig.1, the duration of the zone of film boiling depends uniquely on the specific water discharge (V/F) per unit surface being cooled.

Figure 2a shows the dependence $q_{2cr} = f(V/F)$ obtained from processing the test data. In the range up to 20 $m^3/m^2 \cdot hr$, the second critical load is located

at the level of the values obtained by Kutateladze and Borishanskiy. At greater discharge, the second critical load increases markedly since the instant of film rupture occurs much sooner.

The test conditions were as follows: distance from injector to surface being cooled, ℓ = 150 mm, t_{init} = 1050°C, water pressure upstream of injector P_{init} = 9.8 × 10^4 N/m^2, and coolant temperature t_{wa} = 20°C. A departure from these conditions leads to a change in the value for q_{2cr}, although within relatively narrow limits. Maximum variation is obtained at an increase in the distance ℓ. A lesser effect is exerted by the initial surface temperature t_{surf}, pressure, and temperature of the cooling water.

In the investigation of the jet cooling, it was clarified that the value of the second critical load increases greatly with an increase in discharge rate W (Fig.2b). At a velocity of W > 16 m/sec, the value for q_{2cr} coincides with the first critical load. This means that in the given case, for all practical purposes, no film regime zone is present. /34

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